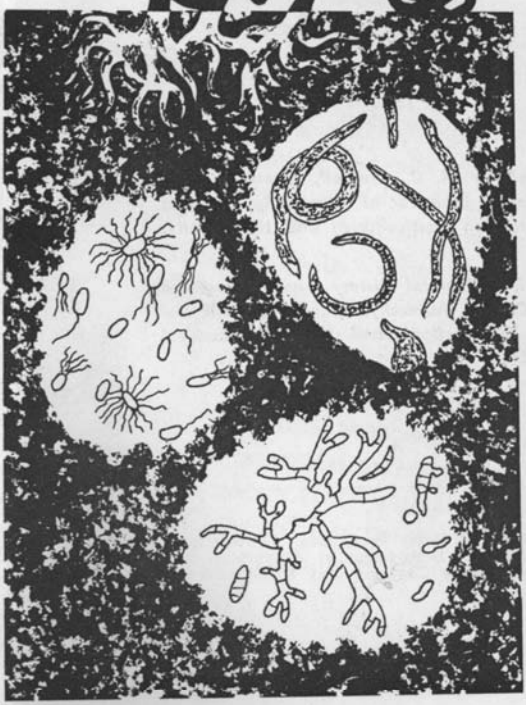
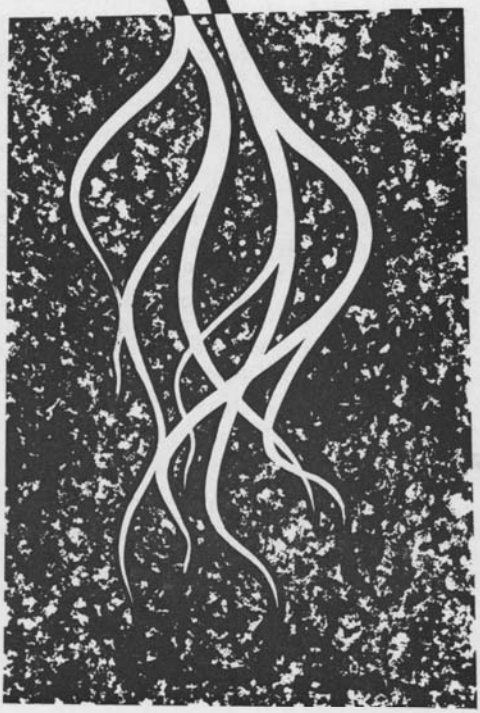
SOIL DISINFESTATION

Methods and Materials





UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE · COOPERATIVE EXTENSION SERVICE CIRCULAR 893

CONTENTS

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SOIL DISINFESTATION

Methods and Materials

THE PURPOSE OF SOIL DISINFESTATION IS TO DESTROY disease-inducing organisms (bacteria, fungi, and nematodes), insects, and weed seeds in the soil. This eliminates the need to change the soil in greenhouses, cold frames, hot beds, and other plant beds. Soil disinfestation should be an important part of the commercial grower's sanitation program. This circular is intended to help the grower produce healthy, vigorous plants through proper disinfestation methods. (Home gardeners interested in this subject should consult University of Illinois Circular 793, *Soil Sterilization Methods for the Indoor Gardener.*)

GENERAL PRECAUTIONS AND SUGGESTIONS

Soil condition. The soil must be loose and easily crumbled so that it can be thoroughly penetrated by heat or chemicals. All lumps, trash, and clods should be broken up, and old plant debris — especially large diseased roots — should be removed. Soil should be in good planting condition when treated. It should be moist enough to permit seed germination, that is, enough to make the soil hold its shape when squeezed in the hand. Do not treat when soil is excessively wet or dry.

Soil amendments. All soil amendments (such as manure, peat, compost, other humus material, sand) must be added before treating. It is particularly important that organic matter is well decomposed.

When using soil fumigants, do not add fertilizers containing ammonia or ammonium salts to the soil at or near the time of treating. Use only fertilizers containing nitrate until the soil temperature is above 70° F. and the crop is well established.

Treating tools. When using steam or methyl bromide, treat tools (hoes, rakes, trowels, markers, shovels, spading forks), clay pots, flats, and rubber footwear by laying them on top of the soil and under the gastight cover. Otherwise, dip them in a 1:20 formaldehyde solution after each use in contaminated soil and before using in treated soil. Boards or concrete at the edges of the bed should also be treated.

Avoid reinfestation of treated soil. Do not transplant seedlings or other plants from untreated or contaminated soil into disinfested soil. Soil is easily recontaminated by nonsterilized flats or pots, tools containing small bits of untreated soil, and contaminated water which

is spattered by careless watering habits. Also, guard against pathogens in and on seed and other plant material, unsterilized compost or manure, or gardeners' hands and feet.

Wait before planting. After steaming, wait a day or two before seeding or planting. When chemicals are used, it may take two to four weeks to aerate the soil before it is safe to seed or plant. (See "Application and Remarks" under specific chemicals in Table 2.) Soils that are high in organic matter or clay, excessively wet, or are treated at low temperatures may retain the chemical at toxic levels for even longer periods of time. Follow the manufacturer's directions on the label. A week after treating with chemicals, work the soil at least once to a depth of several inches to allow gas to escape.

Other precautions. After you decide whether you will use heat or chemicals to disinfest soil, read the special precautions outlined under "Treatments Using Heat," below, and "Treatments Using Chemicals," page 12.

TREATMENTS USING HEAT

Precautions

Temperature and time. When using steam, do not let the soil temperature rise much above 180° F. or leave the steam on too long. Use an accurate thermometer. Do not guess. Hold the coolest spot in the soil at a temperature of 180° for 30 minutes, or turn the steam off when the soil temperature reaches 200°. The soil will not heat up at the same rate, so it is essential that the soil temperature be measured in many locations to make sure it is up to 180°. Check the corners and along edges of benches and ground beds, especially near where the steam is injected.

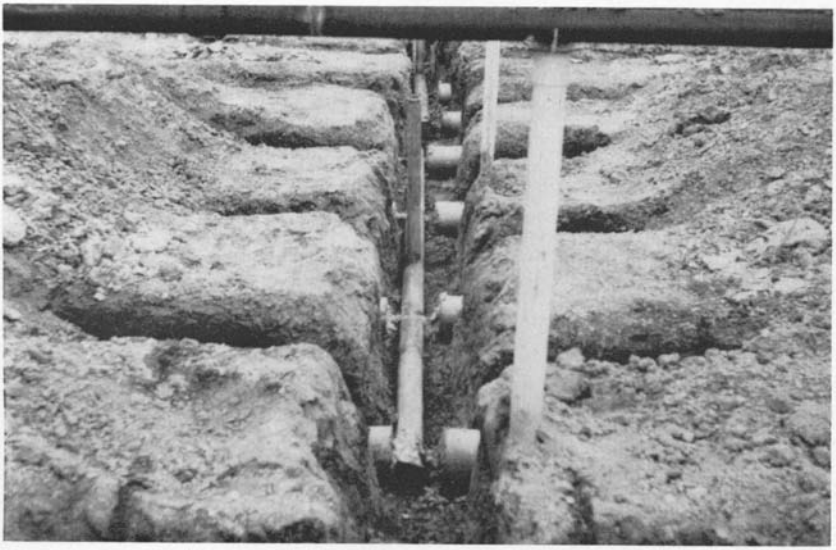
Pressure. When steaming large quantities of soil, use a pressure between 15 and 100 pounds per square inch. Allow at least a 1½-inch opening for steam.

Boiler compounds. Chromate materials are especially toxic to plants and should not be added to a boiler used for soil disinfestation.

Methods

There are several ways in which heat can be used to disinfect soil.

Tank or vault steaming. Flats full of soil can be placed in a large tank or vault and sealed in. The tank is then filled with steam at a pressure of several pounds and held for an hour or longer. Flats should be stacked in racks or at least be separated by blocks of wood. This allows free circulation of the steam.



Parallel underground drain tiles (shown buried in the soil) running the length of the greenhouse. Cross-headers and risers connect the tile to the steam line.

Underground tile method. A steam boiler is needed to make steam under pressure. A 50-horsepower boiler will steam about 500 square feet of bed satisfactorily to a depth of 16 to 22 inches in four to eight hours. In one or two hours, sterilization can be effected to a depth of 9 to 15 inches. The heating pipes in the greenhouse may be used for carrying steam from the boiler to a group of buried tile lines.

Use 3- or 4-inch cement or agricultural drain tile laid in parallel rows 12 to 20 inches apart at a depth of 10 to 12 inches below the soil surface. The distance and depth depend principally on the nature of the soil and depth of cultivation. The heavier the soil, the closer the drain tile should be placed. Pipes from the steam boiler are connected to the tile lines by a short branch pipe extension. The pipe should reach several feet into the drain. Valves should be placed in the conducting pipe so that a combination of drains can be treated at once, depending on the capacity of the boiler. Broken stone placed on each joint aids the steam in penetrating the soil. The opposite ends of each string of tiles should be left open until steam flows freely and then they should be closed. For best results, cross-headers should be placed approximately every 50 feet.

The temperature of the soil farthest removed from the steam inlet (or the coldest spot) should be kept at 180° F. for at least 30 minutes (160° for one to two hours). A longer time is better for heavier soils.

Determine the temperature by inserting thermometers into the soil at different places and at various depths. In ground beds, it is usually sufficient to raise the temperature at the soil surface to 180° if the soil is well loosened before steaming. Heat is retained longer by covering the soil with plastic, canvas, Sisalkraft paper, or commercially prepared rubberized sterilizing cloths.

Underground pipe method. This method is especially adapted to raised benches, although it may also be used in ground beds. It is basically the same as the underground tile method. Use 1½- to 2-inch pipes bored with 3/16- to ¼-inch holes from 6 to 12 inches apart, or use agricultural tile.

In benches, lay pipes or tile about 1 inch from the bottom (6 to 8 inches deep), and 12 to 14 inches apart, with the perforations on the underside. If placed in ground beds, the pipes or tile should be about 15 inches deep and about 18 inches apart. Install pipes as a permanent fixure or remove after each treatment to avoid deterioration. For easy removal, fasten wires at 10- to 15-foot intervals when the lines are being laid. Extend the wires far enough above the soil surface to make it possible to grasp them easily.

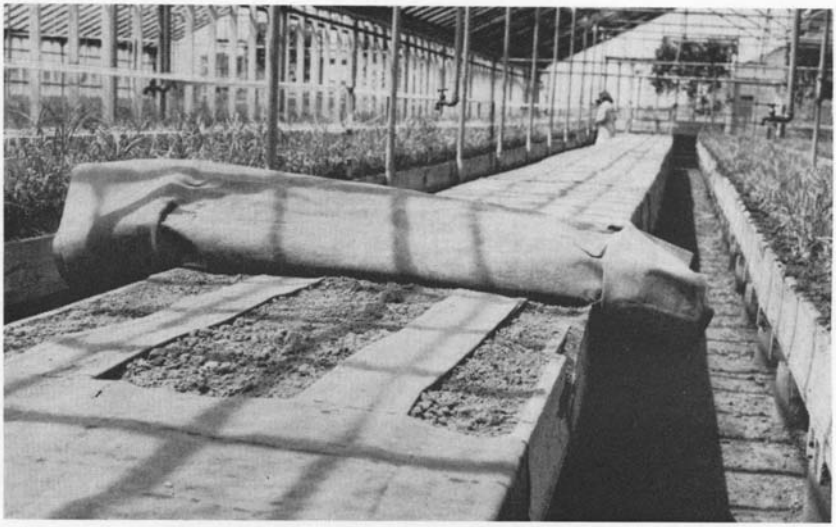
Ground beds with concrete bottom showing agricultural tile laid for soil sterilizing. The tiles are covered with soil, and steam is run through the lines until the soil is thoroughly heated. After steaming is completed the tiles may be left in position or removed.

Steaming a greenhouse bench under a plastic cover. Note that the plastic goes all the way to the floor where it is weighted down. Pots, flats, and tools stacked under the bench are disinfested along with the soil.

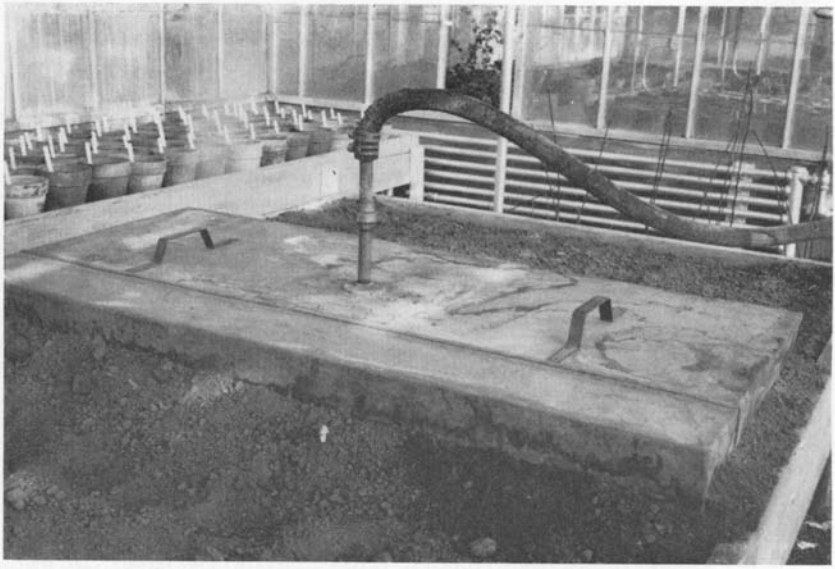
Aboveground tubing method. Lay 8- to 10-foot sections of aluminum alloy tubing on top of the soil. Leave 1-inch spacings between sections. Lead steam directly from the boiler line into the tubing. Drill small holes alternately on opposite sides of the tubing. The only way to determine the exact size and spacing of the holes is by trial. As a rule, the nearer the holes are to the steam inlet, the larger or closer together they must be. In some installations the holes are ¼ inch in diameter, from 18 to 24 inches apart near the steam inlet, and as much as 36 inches apart at the opposite end.

Usually it is best to treat no more than 100 linear feet of bench or bed space at a time. If the bed is long, lead the steam into a T-coupling at the center of the bed, just above the soil surface.

When the tubes are laid in position, on top of the soil, 12 to 15 inches apart, cover the soil and tubes with a plastic (vinyl or polyethylene) cover, plastic-impregnated fabric, Sisalkraft paper, or rubberized sterilizing cloth, and tack or weight it along the margins to keep the steam in. Use the same temperature and time as for other steam-sterilizing methods (see text above).



A greenhouse ready for the Thomas method of steam sterilization. Steam is introduced into canvas hose at one end of the bench. The other end of the hose is blocked off. A portion of the cover has been rolled back to show how the hose is laid.



The inverted-pan sterilizer in use on a greenhouse bench.

The Thomas method. This labor saving and effective method utilizes strips of porous canvas hose laid about 18 inches apart on top of the soil. The hose may run the full length of the bench and is connected to a steam outlet. The bench is covered with specially-treated, steam-proof canvas that hangs about 1 foot over each side of the bench, battened to the sides of the bench where necessary. Steam is turned on under pressure to fill the full length of the hose and is allowed to penetrate into the soil. Use the same temperature and timing as described above.

The inverted-pan method. This method is especially suitable for treating soil in shallow benches and flats but may also be used on small ground beds if the soil is well loosened before treatment. The reinforced steel, 16- or 18-gauge galvanized iron or wooden pan may be any desired shape to fit over a section of bench or bed area. It should not be more than 70 to 75 square feet in area, but at least 8 inches deep. Before steaming, press the pan firmly into position. You may have to weight the pan down with stones or sandbags to hold it in place.

A flexible 1-inch hose connects the steam line or portable boiler to a short pipe, fitted with hose connections. The pipe is inserted through the wall of the pan. Use the same temperature and timing as for other steam-sterilizing methods. Usually ½ to 1½ hours, at steam pressure of 80 to 100 pounds per inch, is sufficient.

Flash-flame pasteurizers. These are popular with commercial growers and pasteurize about two cubic yards of soil an hour. The equipment — a heated cylinder 8 feet long and 20 inches in diameter — is adapted from a tar-melting machine used in road construction. A kerosene-burning blowtorch throws a continuous flame into the lower end of the slightly sloping cylinder. The cylinder is turned about 40 times per minute by means of a 1½ horsepower motor (gasoline or electric). Soil is shoveled into the upper end of the cylinder just fast enough to bring its temperature between 175° and 190° when it drops out pasteurized at the lower end. For details see Cornell University Bulletin 875, "New Flash-Flame Soil Pasteurizer."

Effects of Soil Disinfestation by Steam

When soil is "sterilized" by steaming at 180° for 30 minutes, all organisms living in the soil are *not* killed (Table 1), and therefore, a better term to use is soil disinfestation. Fortunately, most pathogenic (disease-causing) organisms are destroyed at relatively low temperatures so there really is no need to completely sterilize the soil. In fact,

The flash-flame pasteurizer developed at Cornell University.

"over-sterilization" or "overcooking" the soil may cause harmful results.

Physical effects. After steaming, heavy soils in particular may become more granular, with improvement in drainage and aeration. These soils, however, may be more difficult to wet thoroughly since water flows rapidly through non-capillary pores and may not wet the capillary pores. Therefore, several applications of water may be needed to thoroughly wet all the soil particles.

Biological effects. Steaming at 180° for 30 minutes kills most soil insects, weed seeds, and pathogenic organisms (Table 1). Unfortunately, many beneficial bacteria are also destroyed. The bacteria that convert ammonium forms of nitrogen to nitrate nitrogen are killed, but spore-forming, ammonifying organisms that convert organic matter to ammonium forms of nitrogen are difficult to kill. As a result, these organisms increase rapidly after steaming. Even 180° for six hours will not kill all ammonifying organisms.

Disinfestation of soil greatly reduces the number of soil microorganisms for the first few days after treatment. Populations of surviving organisms gradually increase until they exceed that in untreated soil. Also, because the first organisms that return after treatment meet no severe competition, it is important that the soil does not become recontaminated with plant pathogens. Through careless introduction of

Table 1. — Temperatures Necessary to Kill Plant Pathogens and Other Harmful Organisms

Temperature, Fahrenheit[1]	Organisms Killed
115	Water molds
120	Nematodes
125	*Rhizoctonia solani* (causes seedling damping-off)
130	*Botrytis* gray mold
140	Most plant-pathogenic fungi and bacteria, worms, slugs, centipedes
140–160	Soil insects
160	All plant-pathogenic bacteria; most plant viruses
160–180	Most weed seeds
200–212	Resistant weed seeds and resistant plant viruses

[1] Most temperatures indicated are for 30-minute exposures with moist conditions. Adapted from: Baker, K. F., and Roistacher, C. N., Heat Treatment of Soil, Sec. 8, The U. C. System for Producing Healthy Container-Grown Plants. California Exp. Sta. Ext. Ser. Manual 23, pp. 123-137, 1957.

a disease-causing organism into "sterilized" soil, losses can become *more* severe than they were originally.

Chemical effects. A rapid accumulation of ammonium nitrogen (NH_4+) occurs in soils after steaming because the nitrifying bacteria, but not the ammonifying bacteria, are completely destroyed. Although ammonium nitrogen can be utilized by plants, it can build up in quantities large enough to "burn" roots and foliage. Large amounts of ammonia may accumulate in soils high in organic matter or soils to which manure has recently been added. The fresher the manure the greater the problem.

Soluble salts increase in soils after steaming due to a release of adsorbed salts into the soil solution. This release is greater for soils high in humus or manure or where the soil was heavily fertilized prior to steaming.

In some soils (particularly unglaciated soils in southern Illinois) steam treatment greatly increases the exchangeable (soluble)-manganese content of the soil. Oxidizing bacteria, which fix manganese in the soil, are destroyed by sterilization. High soluble-manganese levels following steaming may cause manganese toxicity.

In poorly aerated or wet soils, nitrites (NO_2-) which are toxic to plant growth can accumulate. Such injury is rare.

Water-soluble organic compounds, toxic to plants, may be formed by partial breakdown of organic matter. Little information is available on the nature of such organic-matter residues.

Avoid toxicity problems. Do not steam for a longer time or at a higher temperature than given under Precautions, Treatments Using

Heat, page 4. Oversterilization increases the problems due to soluble salts, manganese toxicity, and toxic organic compounds.

Leaching heavily with water is the only way to reduce hazards due to soluble-manganese levels, soluble salts, and soluble organic compounds. However, leaching also removes soil nutrients, increases the danger of recontamination, may delay planting (especially in winter months), and increases costs.

Broadcasting 5 pounds of superphosphate or gypsum (calcium sulphate) per 100 square feet, either before or after steaming, followed by a light watering will help reduce the release of ammonia.

Transplanting immediately after the soil is cooled (below 85° F. at 6 inches) will re-inoculate the soil with nitrifying bacteria before toxic levels of ammonia can accumulate. Along with this, the new plants should be watered well and the soil kept moist so that the soluble salt concentration will be diluted.

Aging soil for several weeks enables the natural biological balance to develop. Such a practice, however, increases storage costs of the disinfested potting soil. Also, a delay may be brought about at a time when seedlings and cuttings are ready for planting.

TREATMENTS USING CHEMICALS

A number of volatile chemicals (Table 2) are available for treating the soil to control nematodes, fungi, bacteria, and weed seeds. Some fumigants control all of these pests while others are specifically for nematodes or fungi.

Excellent literature on calibration of equipment is available from fumigant suppliers. Fumigants are marketed as liquids, granules, and gases.

Precautions

Temperature. For chemical treatment, the soil temperature at a depth of 4 to 6 inches should be 50° to 85°, to permit effective gas dispersion. Certain soil fumigants containing dichloropropenes can be used successfully at soil temperatures as low as 40°.

Time for treatment. Summer or fall is the ideal time for chemical treatment of soil; crops have been harvested and soil temperatures are best for fumigation.

Safety. When using soil fumigants observe the following safety precautions:

1. *Avoid inhaling fumes.* The chemicals are often irritating to the membranes of the mouth, nose and throat.

2. *Wear safety goggles* to protect the eyes.

3. *Avoid spilling chemicals on the skin, clothing, or shoes.* If this should happen, wash the skin promptly with generous amounts of soap and water. Remove affected clothing or shoes immediately. Clothes should be washed and shoes aired until all odor of the fumigant has disappeared.

4. *Corrosion.* These materials are corrosive to certain metals, e.g., aluminum, magnesium, and their alloys. Applicators should be rinsed with kerosene or fuel oil immediately after use. Do not use water.

5. *Proper storage.* Store fumigants in tightly closed containers in a cool place away from food and feed, and inhabited dwellings. Keep away from heat and open flame. Avoid freezing.

6. *Always follow manufacturer's directions carefully!*

7. *Avoid plant damage.* Most chemical fumigants, especially gaseous ones, *cannot be used* in a greenhouse with living plants. Fumigants used outdoors should not be applied close to valuable plant materials. Growers should post warning signs when using dangerous chemicals in a greenhouse or confined area.

Methods of Applying Liquid Fumigants

A hand applicator is suitable for treating small areas. It consists of a container for the fumigant, a long, hollow, pointed base for penetrating the soil, and a plunger or trip device. When the plunger is

Fumigating a small area using a precision handgun applicator. Note that the soil surface was first marked off into squares.

Table 2. — Soil-Disinfesting Chemicals and Methods of Application

Treatments Materials, Brands	Controls	Application and Remarks
Formaldehyde (37- to 40-percent solution in water and methanol)	Damping-off, seedling blights, other soil-inhabiting disease organisms, soil insects, soft or germinating weed seed. Disinfectant for tools, equipment, and storage areas. Also a seed disinfestant. Does not control nematodes.	Sprinkle 3 tablespoons of formaldehyde diluted with 4 to 6 times that much water on a bushel of soil (32 quarts); 1 tablespoon in ½ cup of water treats a florist's flat of soil. Mix in thoroughly with shovel or hoe on flat surface. Put treated soil in flats, pots, or leave in pile and cover with plastic, wet burlap, or canvas for 48 hours. Drench soil in plant beds or seed flats using 1 gallon in 49 gallons of water (1 cup in 3 gallons) and apply slowly ½ to 1½ gallons per square feet, using a sprinkling can. Cover the soil. After 2 to 4 days remove cover, work soil, and plant when all odor is gone. Never use in greenhouse where plants are growing. Do not plant seed of cabbage family in formalin-treated soil.
Captan, 50 percent WP; thiram, 65 to 75 percent WP; zineb, 75 percent WP	Seed rot, damping-off seedling blights in greenhouse benches, flats, pots and hotbeds	Soil should be loose, fine, and fairly dry. Apply ½ ounce dust per square foot. Mix thoroughly with top 2½ to 3 inches of soil. Seed can be planted immediately after treatment. May also be used as a soil drench, 1 tablespoon per gallon, at the rate of 1 pint per square foot. Repeat at 5-day intervals if disease persists.
Semesan, Pano-Drench, Morton Soil Drench C, Panogen Soil Drench (all contain mercury)	Seed rot, damping-off seedling blights in greenhouse benches, flats, pots and hotbeds	Mix with water and apply as drench to loose, level, fairly dry soil. Follow the manufacturer's directions. Apply with a sprinkling can. Plant when treated soil has dried sufficiently, if the package label does not state otherwise.
PCNB, Terraclor, Terracap 10-10 Dust, Ortho PCNB 20 Dust, Miller's Terraclor Dusts, Monsanto PCNB 80-percent Dust Concentrate, etc. (pentachloronitrobenzene)	Certain disease-causing fungi, e.g. Rhizoctonia, Botrytis, Sclerotinia, Sclerotium, etc.	Various application methods including suspension in transplant water, soil surface sprays or dusts, and dry mixing in upper 4 to 6 inches of soil. Sometimes mixed with ferbam, captan, thiram, Dexon, folpet (Phaltan), etc. Thorough mixing with the soil is essential. Follow the manufacturer's directions.
EDB, Ethylene Dibromide, Dowfume W-85, Soil-Fume 80-20 and 60-40; Trona Bromofume 40 and 85; Ortho Ethylene Dibromide 83 Soil Fumigant (1,2-dibromoethane)	Nematodes, soil insects, garden centipedes	Apply at least 4 to 8 inches deep, at 10- to 12-inch intervals, with special tractor-mounted equipment. Do not use where onions will be grown within 3 years. Wait 2 or 3 weeks before planting. Follow the manufacturer's directions. EDB is recommended for fall treatment only.

D-D Soil Fumigant, Telone, Stauffer DD Soil Fumigant, Vidden D, Ortho D-D Soil Fumigant, Nemafume (mixed dichloropropenes)	Nematodes, soil insects	Apply about 6 inches under soil surface like EDB at 10- to 12-inch intervals. Do not plant until 2 to 4 weeks after treatment. Use at a heavier rate on muck (peat) soil. Follow the manufacturer's directions.
Chloropicrin, Larvacide 100, Picfume, etc. (tear gas or trichloronitromethane). Larvacide Soil Fumigant contains 93.5 percent chloropicrin and 6.5 percent EDB; Nemex is a 50-50 mixture of chloropicrin and dichloropropenes	Damping-off, seedling blights, other soil-inhabiting disease organisms, weed seeds, nematodes, soil insects	Apply with special injection equipment in holes 4 to 6 inches deep in rows about 10 inches apart, spaced so that holes are 10 to 12 inches apart in rows. Inject chemical into each hole and close by stepping on the hole. After treating, apply a gas-proof cover or sufficient water to soak upper inch of soil to seal in the gas. Maintain water seal for 3 days. Do not plant in treated soil until all traces of chloropicrin have disappeared. This may be from 12 days to 4 weeks. Use a chloropicrin mask and canister while working.
Dorlone (mixture of 75.2 percent Telone and 18.7 percent EDB)	Nematodes	Same as for D-D above. Use at rate of 12 gallons per acre. Do not use where onions will be grown within 3 years.
Methyl Bromide, Dowfume MC-2, Dowfume MC-33, Brozone, Pano-Brome, Pano-Brome CL, Pestmaster Methyl Bromide, Picride, Profume, Trizone, Great Lakes Brom-O-Gas, etc. (methyl bromide, usually with a small amount of chloropicrin added)	Nematodes, grubs, cutworms and other soil insects, weed seeds, damping-off, seedling blights, other soil-inhabiting disease organisms	Gas in pressure cans or cylinders. Must be applied with a special applicator under a *gas-proof* plastic cover. To kill soil fungi use 3 to 4 pounds per 100 sq. ft. For other pests use 1 to 2 pounds. For field application, use about 400 lbs. per acre when applied by continuous-surface, multiple-row machine. A 7 to 10 day wait is needed between treating and planting. Good in cold frames, greenhouses, and outdoor beds. Extremely poisonous. Do not use before planting onions, celery, carnations and snapdragons.
SMDC, Stauffer Vapam Soil Fumigant, Chem-Vape, DuPont VPM Soil Fumigant (32.7-percent sodium N-methyl-dithiocarbamate)	Soil-inhabiting disease organisms, nematodes, many germinating weed seeds, soil insects	For clay soils use 1½ to 2 quarts per 100 square feet; for light- and medium-textured soils 1 quart. Sprinkle uniformly over the soil with a sprinkling can, hose proportioner, sprayer, or irrigation system. Cover treated area with gas-proof plastic film for 4 days after treating; or apply water seal to upper inch of treated soil (15 to 20 gallons per 100 square feet). Do not treat more than 100 square feet at a time before applying water seal. When top-treated soil has dried sufficiently, cultivate 1 to 2 inches deep. Do not plant until 3 weeks after treating. Fall treatment is best.

(Table is concluded on next page)

Table 2. — Concluded

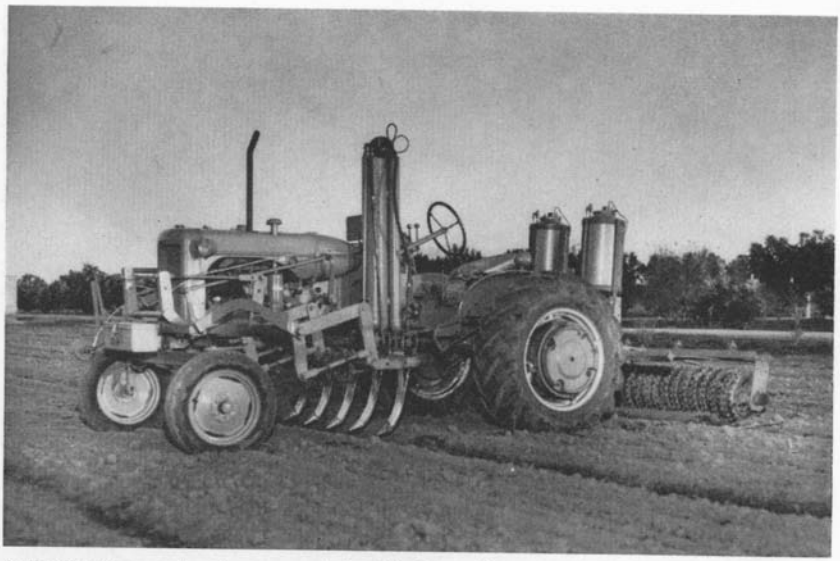
Treatments Materials, Brands	Controls	Application and Remarks
DMTT; Mylone 25 percent WP, 50 percent WP, 85 percent WP, Dust-50; Soil Fumigant M; Miller Mico-Fume 25-D (Mylone) (3,5-dimethyl-tetra-hydro-1,3,5,2H-thia-diazine-2-thione)	Soil fungi, weed seeds, nematodes, soil insects	Apply at a rate of ¾ to 2⅔ pounds per 100 square feet depending on formulation. Wait at least 21 days before planting. Apply as drench or granules. Disc or rake into soil. Use for seed and plant beds. Cover treated area with plastic cover or apply water seal as for SMDC above. Follow the manufacturer's directions. Fall treatment is best.
Vorlex Soil Fumigant (20-percent methyl isothiocyanate and 80-percent chlorinated C_3 hydrocarbons including dichloropropenes)	Nematodes, soil insects, weed seeds, soil-borne fungi	Apply like chloropicrin but use chisel spacings of 8 inches. Pack treated soil and apply water seal or plastic cover. Leave soil undisturbed for at least 4 days. Then cultivate to prevent soil crusting. Do not plant for at least 2 weeks or until all odor is gone. Follow the manufacturer's directions.
DBCP; Nemagon Soil Fumigant; Ortho Nemagon 45 Soil Fumigant; Miller Nemagon 10-percent and 25-percent Granular or No. 2 EC; Stauffer Nemagon 8.6E; Edco Nemadrench; Fumazone, etc. (1,2-dibromo-3-chloropropane)	Nematodes, damping-off *(Pythium)*	Apply like D-D and EDB, as granules mixed with fertilizer or apply alone. Very slow acting. May be safely applied to soil around certain living plants. Seedlings more easily injured than older plants. For some crops it is safe to apply in the row at planting time or later as a side dressing. Follow the manufacturer's directions.
V-C 13 Nemacide (75-percent 0-2,4-dichloro, O, O-diethyl phosphorothioate)	Nematodes, soil insects	May be used as soil drench around certain living plants, for treating potting soil (1 teaspoon per quart of water treats 1 cubic foot of soil), or preplanting treatment. Apply as drench or granules. Work into top 6 inches of soil. Follow the manufacturer's directions.
Bedrench (81 percent allyl alcohol and 11.5 percent EDB)	Nematodes, weed seeds, some soil fungi	Apply like SMDC above. Considerable water and 2-week wait period needed. A seedbed drench. Follow directions.

Plow-furrow equipment applying a soil fumigant. The drag seals the chemical into the soil.

pressed, an exact amount of fumigant is placed in each location. Several models are available which can be accurately calibrated to deliver the exact dosage recommended by the manufacturer.

Before treatment, the soil surface is usually marked off into 8- to 12-inch squares. The fumigant is applied in a diamond pattern by marking injections at the junctions of the cross in the first row and halfway between the second row, at the junctions in the third row, halfway between in the fourth row and so on across the garden or plant bed.

Plow-furrow equipment may be purchased from several companies. The machinery is mounted on a plow. A control block can be mounted on the steering post of the tractor to regulate the delivery rate, which varies with the tractor speed. The fumigant outlet (spray nozzle) is in front of each plowshare. The chemical is placed in the bottom of the furrow and should be covered immediately by soil from the moldboard, to a depth of 5 to 10 inches. A chain or spike-tooth harrow, cultipacker, drag, float, or roller should be dragged behind to close soil openings and level ridges. After treatment, the soil must be disked then compacted and leveled with a roller or spike-tooth harrow.



Allis-Chalmers tractor-mounted chisel applicator, pressure orifice system. Note cultipacker which seals the furrows made by the chisels.

A Morton Soil Fumigator, suitable for treating small acreages.

Tractor-mounted shank or chisel applicators are widely used by commercial growers. The liquid fumigant enters the soil through tubes attached to the rear of a staggered row of cultivator shanks, spaced 8 to 12 inches apart. The chemical is placed in the bottom of the furrow (usually 5 to 10 inches deep) made by the shank or chisel as it is pulled through the soil. These machines must be carefully calibrated to deliver the recommended dosage uniformly. A chain harrow, cultipacker, roller, or heavy drag pulled behind the applicator seals the furrows. The soil should be plowed and worked thoroughly before the fumigant is applied. Small garden tractors equipped with chisels, e.g., the Morton Soil Fumigator, are useful for treating soil in greenhouses, seedbeds, and limited field areas.

In-row, shank-injector method. This is an economical treatment suggested for certain row crops growing on light, sandy soils. One-third the normal broadcast dosage of fumigant is injected into the row. The soil is then usually thrown by sweeps into a ridge over the fumigant. Spaces between ridges are usually 36 or 42 inches for sweet potatoes, and 4 to 6 feet for tomatoes. This provides for a treated strip 1 foot or more wide in which young plants start and gives good

Economical, in-row application. The fumigant is applied by shanks or chisels only to narrow strips where the crop rows are later planted.

protection at a relatively low cost per acre for fumigant. The treated strip must be carefully marked for planting two weeks or more later.

Blade applicator (developed at Oregon State University). A continuous sheet of the chemical is sprayed into the soil through an injection boom mounted in a protected recess behind a blade which is drawn through the soil behind a tractor. The soil should be firmed with a roller or float after treatment.

Application in 8-inch ridges using Vapam or VPM Soil Fumigant. This is a convenient method in certain areas where the soil is loose and sandy. The fumigant is dropped from an applicator mounted just in front of the ridging disc wheels. The ridges are then rolled flat except for a shallow, 2-inch furrow in which crops are planted two or more weeks later, when the chemical fumes have escaped. Fifty pounds or more of the chemical is applied per acre in rows 30 to 42 inches apart. Check with the manufacturer or your chemical dealer regarding recommended rates.

Typical turf area ready for methyl bromide treatment. Straw-filled sacks in place, evaporation pans located, and inlet tubes in position. Crumpled fertilizer bags, inverted baskets, or flower pots may be used instead of straw-filled sacks for polyethylene cover support. This turf renovation treatment kills old vegetation.

Methods of Applying Gaseous Fumigants

Methyl bromide is an extremely poisonous, odorless gas. A gas mask fitted with a black canister must be worn during application and when the cover is removed. This treatment is suggested only for commercial growers who are properly equipped. All necessary precautions must be followed to the letter!

The chemical is available in 1-pound cans or in steel cylinders of various sizes. Most formulations now contain 98 percent methyl bromide and 2 percent chloropicrin. The latter is added as a warning agent. The treatment is made under gas-proof covers (e.g., polyethylene or vinyl plastic). For small soil lots, metal-lined vaults or steel drums may be used. Canvas must not be used.

Disinfestation of tools, containers, and machinery. All materials to be disinfested should be carefully covered with a gas-proof cover, leaving no place for possible leaks. Edges of the cover are weighted down. Leave enough room under the top so that the gas can circulate freely. Place the end of the plastic or copper tube from the methyl bromide container under the cover, with the end passing into open

A tractor-mounted machine applying a highly volatile soil fumigant while simultaneously laying a polyethylene film cover. Practical for controlling pests in plant beds.

A six-row Gandy granular applicator with a land wheel drive.

trays where the liquid methyl bromide is vaporized. Dowfume MC-2 can be vaporized without using evaporating pans. Before treating, the cubic footage of the space must be calculated accurately. Use the fumigant at the rate of 1 to 4 pounds for every 100 cubic feet. The cover is left in place for 48 hours if the temperature is cool (50° to 59° F). Twenty-four hours is sufficient in hot weather (60° or above).

Treatment of seedbeds, coldframes, transplant beds, and other small areas. Prepare the seedbed as you would for planting. Place cover supports at regular intervals to allow free circulation of gas. Then put evaporating pans on the prepared soil area and attach the applicator tubing securely to the pans. The other end of the tubing, connected to the applicator, should be outside the area to be treated. When using 1-pound cans, place one evaporator pan in the center of each 100 square feet. Place the gas-proof cover carefully over the soil area and bury the edges of the cover to a depth of 6 inches. When the cover is securely in place, release the gas with the specially designed applicator following the manufacturer's directions. The cover should be left in place for 24 to 48 hours.

Field-scale application. Tractor-mounted machines are available to apply highly volatile soil fumigants while simultaneously laying a gas-proof cover. Follow the manufacturer's directions implicitly.

Methods of Applying Granular Fumigants

DBCP (primarily **Fumazone** and **Nemagon**), **Mylone**, or other fumigant may be applied with any type of fertilizer or granule distributor that will deliver the granular material 5 to 6 inches below the soil surface. A spacing of 10 to 12 inches is desirable. In-row treatment of widely spaced crops is most economical and gives satisfactory control. Carefully follow the manufacturer's directions.

SOIL DISINFESTATION RECORDS

The commercial grower seeking to reduce plant losses would be wise to take notes on the type and amount of treatment he uses, time of treatment, soil conditions, and the results obtained. Records of this kind are helpful in pinpointing trouble spots that may arise later, and will serve as guides to extension specialists or other technical advisers when they are called upon to evaluate a particular disinfestation program. Defects in programs and procedures often cannot be discovered when it is known that they have been used but all of the specific details have been forgotten.

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